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# Bescheinigung | Certificate | Attestation

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The attached documents are exact copies of the European patent application described on the following page, as originally filed.

Les documents fixés à cette attestation sont conformes à la version initialement déposée de la demande de brevet européen spécifiée à la page suivante.

**Patentanmeldung Nr. | Patent application No. | Demande de brevet n°**

02075210.1

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Der Präsident des Europäischen Patentamts;
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For the President of the European Patent Office

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# Blatt 2 der Bescheinigung
# Sheet 2 of the certificate
# Page 2 de l'attestation

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Applicant(s):
Demandeur(s):
Koninklijke Philips Electronics N.V.
5621 BA Eindhoven
NETHERLANDS

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**Introduction**

To make the DVR system compatible with DVD and CD readout, in general three laser diode are needed, one emitting 405 nm, the second one 650 nm, and the third one 785 nm, in order to be able to read all the existing disks. Due to this purality of wavelengths, designing a binary grating selecting a set of predefined diffraction orders is difficult. The reason for this is that in designing a binary grating one makes use of the fact that the phase introduced by a step height h is different when the wavelength is different. An example of this is for instance explained in PHNL000478EP.P ("Stepped-profile grating for CD/DVD objective lens"). An similar approach could of course also be used when designing a three-wavelength grating. However the fixed values of the wavelength put a severe constraint on this designing method explained in PHNL000478EP.P. As a result in general the binary stepped structure becomes complex, requiring relatively high steps and high efficiency in all the three configurations are hard to obtain.

At the ISOM2001 conference LG Electronics showed in a paper (Pd-29 page 304-305 proceedings) that by employing a birefringent grating that high efficiency for a two-wavelength case have orthogonal polarisation is possible. The three-wavelength case was not addressed here.

**Problem**

The problem is thus how to design a grating which can be used for at least three different wavelengths having a simple structure and high efficiency at each wavelength at predetermined orders.

**Solution**

To solve this problem we propose to make the stepped structure of birefringent material. As a result we can now also make use of polarisation, hence we let the orientation of the polarisation of the three beams do not all have the same orientation. Consequently, for binary gratings there is now an additional parameter which can be used in defining the structure giving rise to more design freedom. The phase introduced by a step height h made of a material having refractive index n at wavelength λ is given by

$$\Phi = 2\pi \frac{h(n-1)}{\lambda} \qquad (1)$$

Consequently, when the wavelength changes the phase introduced by a step changes. Furthermore, when chancing the polarisation and thus changing the refractive index also a change in phase introduced by the step is generated. Combining both effects for the three wavelengths system, designing binary gratings having high efficiency at the desired diffraction order for each wavelength is possible with relatively simple grating structures.

**First embodiment (or "embodiment 1")**

Consider a birefringent material having an extraordinary refractive index of $n_e$=1.5 and an ordinary refractive index $n_o$=1.6 These values are typical for UV curable birefringent polymer material. For the moment we neglect the change in refractive index due to difference in wavelength. The birefringent grating is aligned in such a way that when the polarisation is the light is in the x-direction ($p_e$) then $n_e$ is selected and when polarised in the orthogonal y-direction ($p_o$) then $n_o$ is selected. Consider the case where the three wavelengths are given by $\lambda_1$=405nm, $\lambda_2$=650nm and $\lambda_3$=785nm. We want to design a binary grating selecting zero order diffraction for $\lambda_1$, and first order diffraction for $\lambda_2$ and $\lambda_3$. Consequently, the binary steps in each zone (see also PHNL000478EP.P) must be chosen such that they introduce an integer multiple of $2\pi$ in the $\lambda_1$ configuration. Depending on the polarisation chosen for the $\lambda_1$ configuration we find that this height must be for $p_o$

$$h^o_{405} = \frac{\lambda_1}{n_o - 1} = 0.675\,\mu\text{m} \qquad (2)$$

and for $p_e$

$$h^e_{405} = \frac{\lambda_1}{n_e - 1} = 0.810\,\mu\text{m} \qquad (3)$$

In Table I the step height giving rise to a phase step of $2\pi$ in each configuration is tabulated. In Table II the phase introduced by a step of $h^o_{405}$ or $h^e_{405}$ in the $\lambda_2$ and $\lambda_3$ configuration is given.

| Wavelength (nm) | $h^o$ (µm) | $h^e$ (µm) |
|---|---|---|
| 405 | 0.675 | 0.810 |
| 650 | 1.083 | 1.300 |
| 785 | 1.308 | 1.570 |

Table I

| | $\Phi(\lambda_2,p_o)/2\pi$ | $\Phi(\lambda_2,p_e)/2\pi$ | $\Phi(\lambda_3,p_o)/2\pi$ | $\Phi(\lambda_3,p_e)/2\pi$ |
|---|---|---|---|---|
| $h^o_{405}$ | 0.623 | 0.519 | 0.516 | 0.430 |
| $h^e_{405}$ | 0.748 | 0.623 | 0.619 | 0.516 |

Table II

From these tables it follows that when employing the same polarisation in all these configurations we observe that phase jumps in the $\lambda_3$ configuration is approximately $\pi$. Consequently, only two substantially different phase steps in this configuration are possible, making the design of a simple binary grating, giving rise to high efficieny in the first order diffraction, not possible. When we employ different polarisations in the three configurations such a simple design is possible. Consider the following case where for $\lambda_1$ we use $p_e$, for $\lambda_2$ we use $p_e$, for $\lambda_3$ we use $p_o$.

In Table III the phase introduced by a step heights m $h^e_{405}$ (m integer) in the $\lambda_2$ and $\lambda_3$ configuration.

| m | $\Phi(\lambda_2,p_e)/2\pi$ mod 1 | $\Phi(\lambda_3,p_o)/2\pi$ mod 1 |
|---|---|---|
| 1 | 0.623 | 0.619 |
| 2 | 0.246 | 0.238 |
| 3 | 0.869 | 0.857 |
| 4 | 0.492 | 0.476 |
| 5 | 0.115 | 0.095 |
| 6 | 0.738 | 0.714 |
| 7 | 0.361 | 0.333 |
| 8 | 0.984 | 0.952 |

Table III

Table III shows that the phase introduced in the $\lambda_2$ and $\lambda_3$ configuration are approximately the same. There are 8 substantially different phase possible.

We follow now the same approach as in PHNL000478EP.P to design the binary grating structure selecting zeroth order diffraction for $\lambda_1$ and approximating a sawtooth-like blazed grating for the $\lambda_2$ and $\lambda_3$ configuration. Since with the above construction the phase steps introduced in the $\lambda_2$ and $\lambda_3$ configuration are almost the same it is now straightforward, employing the same method as described in PHNL000478EP.P, to design Damman like binary grating structure selection first order diffraction for both $\lambda_2$ and $\lambda_3$.

**First example of the first embodiment**

In Table IV a grating having 4 subzones (similar as the example tabulated in table 4 of PHNL000478EP.P) is given showing high efficiency for both $\lambda_2$ and $\lambda_3$. The values "$\Phi/2\pi$ ideal" are determined from Equation (1) of PHNL000478EP, this equation being incorporated herein by reference. The values of efficiency are determined from Equation (2) of PHNL000478EP, this equation being incorporated herein by reference

| Subzone | $\Phi/2\pi$ ideal | m | $\Phi(\lambda_2,p_e)/2\pi$ mod 1 | $\Phi(\lambda_3,p_o)/2\pi$ mod 1 |
|---|---|---|---|---|
| 0.00-0.25 | 0.125 | 5 | 0.115 | 0.095 |
| 0.25-0.50 | 0.375 | 7 | 0.361 | 0.333 |
| 0.50-0.75 | 0.625 | 1 | 0.623 | 0.619 |
| 0.75-1.00 | 0.875 | 3 | 0.869 | 0.857 |
| Efficiency | 81.1% | | 81.0% | 80.5% |

Table IV

Note that due to the extra freedom introduced due to the polarisation in combination with the freedom in choosing $n_e$ and $n_o$ high efficiencies in all the cases can be obtained.

**Second example of the first embodiment**

In Table V an example employing 6 subzones is shown in which the efficiencies are even higher.

| Subzone | $\Phi/2\pi$ ideal | M | $\Phi(\lambda_2,p_e)/2\pi$ mod 1 | $\Phi(\lambda_3,p_o)/2\pi$ mod 1 |
|---|---|---|---|---|
| 0.0000-0.1667 | 0.0833 | 5 | 0.115 | 0.095 |
| 0.1667-0.3333 | 0.2500 | 2 | 0.246 | 0.238 |
| 0.3333-0.5000 | 0.4167 | 4 | 0.492 | 0.476 |
| 0.5000-0.6667 | 0.5833 | 1 | 0.623 | 0.619 |
| 0.6667-0.8333 | 0.7500 | 6 | 0.738 | 0.714 |
| 0.8333-1.0000 | 0.9166 | 8 | 0.984 | 0.952 |
| Efficiency | 91.2% | | 87.4% | 87.6% |

Table V

**Second embodiment (or "embodiment 2") and third embodiment (or "embodiment 3")**

The second and third embodiments relate to the cases where a step height h gives rise to the same phase in two of the three configurations.

The first embodiment relates to the case where the step height h is chosen such that the phase introduced in the two configurations it equal to $2\pi$. The stepped subzone distribution of the grating made of integer multiples of this height h will then select zeroth order diffraction for these two configurations. By proper design this structure can than select a predefined diffraction order (or orders) at the remaining third configuration. Example the grating can be designed to generate three spots at one configuration and having no effect at the other two configurations.

The second embodiment relates to the case where the step height is chosen such that at the remaining third configuration a phase of $2\pi$ is generated. In this way we select zeroth order diffraction at this configuration. At the other two configurations we can now select by proper design the same diffraction order (or orders). The described explicit embodiment on the previous page is an example.

The above is possible when the following constraint is met. Choose $\lambda_a$ as reference wavelength. We want to have that a height h introduces the same phase for the other two configurations $\lambda_b$ and $\lambda_c$. Let $n_a$ be the refractive index of the birefringent material for one polarisation and $n_b$ be the refractive index of the birefringent material for the orthogonal polarisation. In order that a step height h introduces the same phase for the two configurations $\lambda_b$ and $\lambda_c$ we must have

$$\frac{\lambda_b}{n_a - 1} = \frac{\lambda_c}{n_b - 1} \qquad (4)$$

From this it follows that $n_b$ must be substantially be equal to

$$n_b = 1 + \frac{\lambda_c}{\lambda_b}(n_a - 1) \qquad (5)$$

With substantially equal we mean that the refractive index n in this polarisation must comply

$$|n - n_b| \leq 0.05 \qquad (6)$$

In order to have an even better efficiencies it must comply with

$$|n - n_b| \leq 0.025 \qquad (7)$$

Example:

$\lambda_b$=650 nm and $\lambda_c$=785 nm and $n_a$=1.5, we find that $n_b$=1.604.

**Application area**

In optical recording OPU employing gratings and three different wavelengths. In particularly this is of importance when considering DVR/DVD/CD compatibility employing a single objective.

CLAIMS

1. An optical scanning device a first information layer, a second information layer and a third information layer by means of a first radiation beam having a first wavelength ($\lambda_1$), a second radiation beam having a second wavelength ($\lambda_2$), and a third radiation beam having a third wavelength ($\lambda_3$), respectively, said first, second and third wavelengths being substantially mutually different, the device comprising:

a radiation source for emitting said first, second and third radiation beams,

an objective system for converging said first, second and third radiation beams on the positions of said first, second and third information layers, respectively, and

a diffractive part arranged in the optical path of said first, second and third radiation beams, the diffractive part including a pattern of pattern elements having a stepped profile designed such that the optical paths pertaining to steps of said pattern element are substantially equal to multiples of said first wavelength, and such that said objective system has:

a first focusing characteristic for said first wavelength wherein said first radiation beam is substantially of the zero order of diffraction, and

a second focusing characteristic for said second wavelength wherein a part of said second radiation beam is of a non-zero order of diffraction,

characterised in that:

said diffractive part is made of a birefringent material, and in that

said stepped profile is further designed such that said objective system has a third focusing characteristic wherein said third radiation beam is of a zero order of diffraction or a part of said third radiation beam is of a non-zero order of diffraction,

at least one of said second and third focusing characteristics differs from said first focusing characteristic, and

at least two of said first, second and third radiation beams have mutually different polarizations.

2. The scanning device according to Claim 1, wherein stepped profile is further designed such that said second radiation beam has substantially its efficiency of transmission for said non-zero order of diffraction.

3. The scanning device according to Claim 1, wherein said pattern element is designed such that the relative step heights between adjacent steps of said pattern element include a relative step height having an optical path substantially equal to $a\lambda_1$, wherein $a$ is an integer and $a>1$ and $\lambda_1$ is said first wavelength.

4. The scanning device according to Claim 1, wherein said pattern element is designed such that said first radiation beam is of the zero-order of diffraction and that said second and third radiation beams are of the first-order of diffraction.

5. The scanning device according to Claim 1, wherein said diffractive part is generally circular and the steps of said pattern element are generally annular.

6. The scanning device according to Claim 1, wherein said diffractive part is formed on a face of a lens of the objective system.

7. The scanning device according to Claim 1, wherein said diffractive part is formed on an optical plate provided between said radiation source and said objective system.

8. The scanning device according to Claim 7, wherein said optical plate comprises a quarter wavelength plate or a beam splitter.

9. A lens for use in an optical device for scanning a first, second and third type of optical record carrier with a beam of radiation of a first wavelength ($\lambda_1$), a second wavelength ($\lambda_2$) and a third wavelength ($\lambda_3$), respectively, the three wavelengths being substantially different, the lens being provided with a diffractive part arranged in the optical path of said first, second and third radiation beams, the

diffractive part including a pattern of pattern elements having a stepped profile designed such that the optical paths pertaining to steps of said pattern element are substantially equal to multiples of said first wavelength, and such that said objective system has:

a first focusing characteristic for said first wavelength wherein said first radiation beam is substantially of the zero order of diffraction, and

a second focusing characteristic for said second wavelength wherein a part of said second radiation beam is of a non-zero order of diffraction,

characterised in that:

said diffractive part is made of a birefringent material, and in that

said stepped profile is further designed such that said objective system has a third focusing characteristic wherein said third radiation beam is of a zero order of diffraction or a part of said third radiation beam is of a non-zero order of diffraction,

at least one of said second and third focusing characteristics differs from said first focusing characteristic, and

at least two of said first, second and third radiation beams have mutually different polarizations